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THOMAS GARY OSENKOWSKY
Radio Engineering Consultant
5 Beechwood Grove
Brookfield, CT 06804
(203) 775-3060

SBE Certified
Broadcast Engineer

NARTE First Class
Certified Engineer

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October 26, 1993

Ms. Donna Searcy, Secretary
Federal Communications Commission
1919 M Street, N.W.
Washington, D.C. 20554

Dear Madam Secretary,

Please find enclosed one original plus four copies of comments in reference to MM Docket 93-177. Attached to each of the comment filings is a copy of a therein referenced paper.

Kindly address any questions concerning this matter to the undersigned.

Sincerely,

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5 Beachwood Grove
Brookfield, CT 06804
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BEFORE THE FEDERAL COMMUNICATIONS COMMISSION

In The Matter of

MM Docket 93-177

Comments Presented to Notice of Inquiry

October, 1993

ORIGINAL

Before the
Federal Communications Commission
Washington, D.C.

MM Docket No. 93-177

The Commission has been petitioned to initiate an inquiry into its Rules governing the adjustment and monitoring of Standard Broadcast AM directional antenna arrays. The petitioners urge to Commission to examine whether certain Rule revisements are in order so as to improve the accuracy of adjustment of these arrays thus decreasing interference in the AM band and reducing the financial burden on licensees who sometimes must bear considerable expense in proving the performance of their antenna systems.

Reference is made in the petition to enhanced computational methods (numerical Method of Moments) that may be employed in order to model antenna arrays on a computer. The most powerful application of Moment Method radiator modeling is base impedance and complex feed current prediction. An ideal array could be defined as one having constant azimuth/elevation pattern shape and size in the bandpass (+/- 10 Khz of carrier) and flat (constant group delay) common feedpoint impedance. By the use of numerical and mathematical matrix techniques, it is possible to design a feeder system which produces optimum pattern and impedance bandwidth while ensuring that the desired radiation pattern shape is achieved.

Considerable attention is given in this comment to feedpoint parameters since sampling of the feedpoint current is often used by licensees to monitor array performance. Note that I use the term 'feedpoint' as opposed to 'base' since the two terms can often be quite different. This was illustrated by Bloomer [1]. An example of feedpoint sampling would be a shielded toroidal transformer located at the Antenna Tuning Unit (ATU) output terminals feeding the tower. A base sample can be a single turn, non-rotatable loop located three meters above the base pier of the tower.

As the petitioners point out, it is often difficult to prove an array's adjustment without a considerable number of field measurements, careful data analysis and expense. Data analysis methodology can vary widely among practitioners. Indeed the same array could be simultaneously examined by different consultants with different conclusions drawn from each.

Each directional station must employ a sampling system which conforms to CFR 47 73.68. Licensees have wide discretion in the design of these systems. The sampling system must perform two important tasks. The first is to provide an indication of the array's complex parameters at the time of initial tuneup. The closer the indicated parameters resemble design values, greater confidence can be had that the array is performing as anticipated. The second function the sampling system has is to provide an monitor of the array's performance on a day-to-day basis.

A useful feature of Moment Method array modeling is the ability to construct a matrix which will relate tower field parameters to base parameters and loop parameters. The location of the current loop is dependent on the current distribution which is a function of driving parameters. If feedpoint sampling is employed, users of the Moment Method will rely on calculated base parameters generated by the computer and adjust the array appropriately. If the sample lines are not of equal length, the length difference is applied to the predicted phase angles.

The various Moment Method computer codes available to the public generally do not produce accurate impedance predictions. There are several reasons for this. They are:

1. The radiator is modeled as a cylinder. In this way, each tower can be considered as a "wire" with a unique x,y,z coordinate. This assumption simplifies the model and saves considerable computer memory and execution time.

2. The ground model is usually assumed to be perfect or near-perfect.

3. The guy wires, base insulator and pier height are not accounted for in the model. Most Moment Method code incorporates a "slice generator" model which assumes an infinitely thin barrier between the ground and feed connection.

4. Most 'base' impedance measurements are not actually performed at the tower base. They are performed at the 'feedpoint' where the base ammeter (and sampling transformer, if DA base sampling is used) is located. The feedpoint is often separated from the base by a lightning retard loop and length of tubing which connects to the ATU. The measured feedpoint impedance contains the influences of isocouplers, lighting apparatus, etc.

Those acquainted with the use of Moment Method analysis recognize the above factors and compensate for the calculated vs measured self impedance differences by slightly (+8% or so) raising the tower height and altering the tower width to more closely match measured self impedances. We are really interested in obtaining a complex value of feedpoint current from the Moment Method program.

Having obtained the complex feedpoint phase angle and currents, we can plug these values into a standard Z matrix mesh equation using measured self and mutual impedance data to derive the drive point impedances and currents. A suitable phasing/coupling system can now be designed with the hopes of producing optimum pattern and impedance bandwidth. If the phasing/coupling system is pretuned, little adjustment should be necessary in the field.

While the above scenario might appear to answer all of the designer's needs, some shortcomings do exist. They are:

1. Considerable inaccuracy in feedpoint parameter prediction due to the cylindrical modeling liberty taken in the Moment Method analysis. Since the tower height was adjusted to produce realistic impedance prediction, the calculated current distribution may no longer be correct especially in a tall tower situation. Since the calculated current distribution may be inaccurate, the desired radiation pattern may not result from using the predicted drive parameters.

2. Further complication in feedpoint parameter prediction can result from installed tower lighting apparatus, isocouplers and other appurtenances. The tower model may have been exaggerated to the point where, although the predicted base impedance matched measured data, the calculated current distribution is far from obtained results thus making base sampling inappropriate for initial array tuneup.

3. The difference between feedpoint and base complex current values can be significant, especially for tall or closely coupled towers. Thus, a sampling loop located at 3 meters above the tower base and a toroidal transformer located inside the ATU may give widely different operating parameters on the antenna monitor.

Base or feedpoint sampling can adequately serve as a day-to-day indicator of array performance. Its value as an initial tuneup tool, however, has been shown to be deficient. This writer has presented a paper (attached) [2] which relates the complex values of field, base, and loop for an actual DA-2 array for the purpose of studying degree of parameter variation versus change in radiation pattern shape. One tower, with an electrical height of 126.2° presents a -1000+j1220 drive point impedance with a change of phase rate of 157° over a 22.4 foot span from the tower base upwards. Base or feedpoint sampling for initial tuneup purposes on this tower in the daytime mode is completely inappropriate.

The paper cited in the previous paragraph points out that the Commission's Rule (CFR 47 73.62) regarding indicated ratio and phase angle tolerances is arbitrary, at best. A variation of +/- 5% of ratio or +/- 3° of phase angle can produce drastically different radiation patterns if base, feedpoint or loop sampling is employed. In other words, a +3° change in base sample might not equal a +3° change in loop or feedpoint sample.

Loop sampling is the best means available to provide an accurate indication of actual array performance. It is, however, the most costly. The following reasons explain the cost factors:

1. The additional sampling line adds cost which can be appreciable in the case of multiple tall towers.

2. The labor for tower rigging and loop installation adds cost.

3. The need for sampling line isolation coils and resonating capacitors can be appreciable. Shunting a tower base with an unresonated coil (usually 80 to 100 microhenries) can severely disrupt the drive point impedance and feedpoint current.

4. The sampling line isolation coils require weatherproof housing which should be apart from the ATU to prevent unwanted coupling. This adds additional expense.

Moment Method computer routines calculate current distribution on individual radiators making loop current and phase prediction an easy task. The modeling shortcomings as described still apply. The loop has the least rate of variation of current magnitude and phase angle thus making it a good sample location despite cost factors.

Up to this point in my comments, I have given in great detail an overview of the issues surrounding how to best sample an array's parameters so as to avoid costly field measurements which can often times prove counterproductive and result in radiation patterns which are operating far from design specifications i.e. we have distorted the pattern to make the numbers look good on paper.

The following solutions are suggested as remedies to the issues and problems outlined above and in the NOI.

1. The Commission needs to standardize a numerical Method of Moments computer program. There are presently a number of computer routines in the public domain which are used by practitioners for modeling AM arrays. Some of these program codes or input data have been modified to produce results which match measured data.

   If the Commission is to allow arrays to be adjusted without the use of field intensity measurements, it is necessary to establish a standard by which the engineering and legal community can rely on to produce accurate and uniform results. I recommend that the Commission investigate the NEC-3GS computer code which is not available to the public. NEC-3GS employs improved ground modeling algorithms.

   The Commission might employ the Naval Ocean Systems Center, the writers of the original NEC or MININEC code, or an ad-hoc committee composed of interested and qualified parties to develop a code which has "user friendly" input/output and mathematical routines specifically written to model typical uniform and nonuniform vertical radiators.

The proposed code would be used in the adjustment phase of a directional antenna system (Form 302) which employs loop sampling as defined in CFR 47 73.68 and discussed later in these comments. The proposed code should be accurate in both the near field (proximity) and far field prediction modes. The use of proximity correction has been accepted by the Commission on a case-by-case basis using various mathematical equations. A uniform code would standardize this practice.

2. CFR 47 73.45(c)(1), 73.45(c)(2), 73.54(c)(1) and 73.54(d) should be amended to delete the requirement for non-directional and directional AM stations to submit to the Commission antenna or common point resistance and reactance data. The Commission should not be burdened with the task of licensing antenna resistance for the purpose of direct power measurements. This data should be kept of file at the station for the carrier frequency only. Presently, CFR 47 73.54(c)(1) requires impedance measurements out to +/-25 Khz of carrier. No useful purpose for the submission of these measurements exists. The Commission has no specifications for impedance bandwidth, thus the data has little value. Some DA stations employ a common point in-line Operating Impedance Bridge giving instantaneous resistance value for power determination.

Many non-directional stations rent tower space and changes in the antenna system affect the base impedance. Deleting the requirement for submitting impedance data would reduce the number of Form 302's and license modifications the Commission has to process. The measured carrier impedance data would be kept on file at the station.

3. CFR 47 73.58(b) should be amended to delete the requirement for RF ammeters located at the base of each element in a directional array using a type approved sampling system. As pointed out earlier in these comments, the feedpoint of a tower is usually the least desirable location for initial tuneup parameter sampling. Thermocouple RF ammeters are susceptible to climatic influences, easily damaged by lightning even with shorting bars attached and subject to shock and vibration by operation of shorting bars. Toroidal ammeters are expensive (roughly five times the cost of a thermocouple ammeter).

CFR 47 73.68 specifies requirements for a sampling system by which the array performance is monitored. At times a discrepancy between the sampling system and base ammeters arises. This writer has witnessed attempts to correct such discrepancies by "phasor tweaking". The results were catastrophic in view of the fact that the base ammeter(s) proved to be out of tolerance, the array was functioning properly as indicated by the type approved sampling system.

4. When field intensity measurements are used to prove the adjustment of a directional antenna system, certain criteria should be applied. I recommend the following wording:

    a. No monitor point will be considered to be acceptable unless at least a 20db maximum to minimum radiation value is able to be measured at the intended location.

    b. The monitor point shall be clear of overhead lines, obvious underground pipes, metallic fences or railings and nearby structures which might influence the readings.

    c. The field intensity meter shall at all times face the array during measurements.

    d. The monitor point shall be chosen to be as permanent and accessible a location as judged by the reader i.e. not in the middle of a construction project.

    Often times, an object(s) nearby to a directional antenna system are determined to be a reradiator and thus comprise an n^{th} element in the array. Field intensity measurements, especially in the directional mode, can be adversely affected by reradiators. Current practice involves determining the Inverse Distance Field at one kilometer from the array. This value, however, can have little value. What we are really interested in is protecting a neighboring station from interference. The neighboring station is usually quite far from the station under measurement. A reradiator is not fed power directly from the coupling system, rather it is in fact a very poor (parasitic) radiator.

    The influence of a reradiator often drops off sharply as distance from the array increases. Careful data analysis and presentation can obviate the effects of the reradiator making detuning unnecessary. This writer has serviced one two tower system with twenty four detuning wires and tuning networks some of which contained G2 capacitors on railroad trestle close to the array. The detuning apparatus was installed in 1959 and removed by this writer in 1978 due to advanced deterioration and prohibitive repair costs. It was easily possible to prove array adjustment using careful data analysis and presentation. The IDF at one kilometer should not be the determining (limiting) factor in proving an array's performance when external influences not under the licensee's control exist. The real interest should be the radiation value at considerable distance from the array where it has the greatest effect i.e. closer to the neighboring station.

The aforementioned use of Moment Method computer codes allows the user to model some reradiators as part of the array. In fact, it is easy to include towers with a field ratio of 0.000. Such towers are those in the array which remain unused in a mode of operation. We can predict with a good degree of accuracy what effects external objects have on a pattern.

In presenting data which is under the influence of external objects it is possible to make numerous measurements at frequent intervals (100 to 300 feet) and graphically determine a sinusoidal pattern to the measured field intensity. Instead of "throwing out" points which do not fit the desired conductivity curve, carefully determining the average radiation along the radial can prove the array to be in proper adjustment even though the measurement interval is more frequent than usually recognized by the AM Branch.

Often times a consultant may find himself in a paradox. Believing that an array is in proper adjustment and being able to prove it. If every reasonable step using modern mathematical techniques is made during array adjustment it is necessary to adopt sophisticated methods of proving the radiation pattern if field measurements are employed.

5. The issue of vertical radiation patterns is raised in the NOI specifically in relation to the adjustment of an array. One of the previously overlooked (although without specific reference) misadjustments of a symmetrical array with unequal height towers is that of its *mode*. That is, for symmetrical arrays there exists 2^{n-1} parameter combinations which produce identical horizontal radiation patterns but different power distributions among the elements, different drive point impedances, and different drive currents. Using the technique of *moding* can greatly improve impedance and pattern bandwidth if not done so in the initial design.

One drawback of moding an array of unequal height towers is the fact that the vertical radiation patterns will not remain the same as does the horizontal pattern. Thus it is possible to cause significant interference at vertical angles and yet demonstrate a horizontal pattern well within specifications.

In order to alleviate this possibility, it is recommended that the Commission adopt a policy of specifying "adjusted to" field parameters if they have been *moded*. If modern computer techniques are used in array adjustment, it should be necessary to demonstrate how the monitored parameters (i.e. the loop current ratio and phase angle) are related to the design field parameters. If the original design parameters are modified it should be necessary to include demonstration in Form 302 that the original pattern is adhered to.

6. Since vertical radiation in excess of design values can cause interference, the Commission is urged to take advantage of the aforementioned numerical modeling techniques in order to examine the behavior of vertical radiators that depart from the standard uniform, guyed type.

   At present, there is no distinction between the various methods of toploading. Two common types of toploading are guy wire and top-hat. The radiation characteristics of these two types of toploading are quite different, however, they are treated as equal insofar as the Rules (CFR 47 73.150) are concerned. Vertical radiation characteristics of various radiator types were examined using numerical techniques [3].

   It is interesting to note that not all of the necessary equations for determining the RMS and field intensity on a particular azimuth/elevation angle are contained in CFR 47 73.150 and Appendix A. Equations for loop current magnitude for the toploaded and sectionalized radiators can only be found in the RADIAT computer program source code. I suggest that Appendix A be merged into CFR 47 73.150 and the aforementioned equations be included therein. The loop current equations are important since the one ohm loss factor [CFR 73.150(b)(1)(i)] is multiplied with the calculated loop current in order to determine the lossy field intensity at a particular bearing/elevation angle.

7. The Commission is urged to place a lesser emphasis on field intensity measurements as a means of determining whether an array is in compliance with the original pattern design. Monitor points often fall victim to nearby construction or other external influences. Climatic variations can adversely affect monitor point readings. A client of mine was inspected on March 17, 1993 at a time when six inches of snow laid on the ground and a steady, heavy rain was falling. The station is located in New England. The nighttime pattern was cited as being out of tolerance on several monitor points. Field intensity measurements performed by this writer approximately one week later, after the snow was melted and the temperature rose to 45°F, indicated that all points were within tolerance given identical antenna monitor readings. One mistake that could have been made was to "tweak" the phasor in order to bring in the monitor points. This is exactly the situation that is to be avoided. Greater emphasis should be placed on sample system indications as opposed to field intensity measurements.

   The "summer-winter" effect has been recognized for many years, especially in New England. One way to check for its influence would be to spot check several points in the major lobe. Similar high readings there would confirm climatic influence.

This writer recognizes that not all arrays might be converted to true loop sampling in order to take advantage of possible relaxed field measurement requirements. It is important therefore to ensure that such measurements be made as accurately and judiciously as practical.

6. Partial proofs of performance must often times be referenced to aged (30 years or more) original proofs, especially for non-d to DA ratios. Performing new non-d measurements involves considerable effort and cost. A land surveyor must lay out the radials and close-in distances for the greatest accuracy. Many times, construction near the antenna site makes access to intended monitor points impossible.

   I recommend that stations which employ (former) 73.68 "type approved" loop sample systems be granted waiver from field intensity measurement verification procedures provided that:

   a. Evidence is presented to show correlation between indicated loop ratio and phase to the design field ratio and phase and how this was achieved.

   b. Each sample line's electrical length be measured and documented using the RF signal null method. This method is recommended over a TDR or other extravagant means since the rudimentary equipment required is easily obtainable for repeatability purposes. The bridge method is likewise applicable.

   c. All sample lines must be solid outer sheath and adequately protected against damage form manmade or natural causes. All connectors employed must be specifically intended for use on the particular line employed.

   d. Supporting field intensity data should be supplied to verify array performance. Such data may be several DA to non-d ratioed measurements demonstrating that the expected power ratio in the protected directions is being achieved.

7. CFR 47 73.62 specifies in an arbitrary manner the tolerances for antenna monitor readings. It has been shown by this writer that sample indications are highly dependent on the placement of the sample elements $_2$. If the above suggested loop sampling methodology is employed, I recommend that computer iteration be performed in order to determine if a 5% and 3° loop tolerance is acceptable in the initial design stage. It would be necessary to convert loop values to field values for each iteration. Computer field parameter iteration is presently used to check array stability.

8. The Commission should delete the requirement for filing plotted conductivity curves for complete or original proofs of performance. This would save licensees considerable expense. Most of these tasks are relegated to a computer and paper plotter. A tabulation of conductivity breaks and distances should suffice for the purpose of data analysis. Graphic representation may occasionally be necessary where it is necessary to illustrate a particular condition.

Closing Comments

The Commission expresses concern over the adoption of newer calculation methods should they conflict with measured data. It is of the utmost importance that a standard numerical method be adopted by the FCC just as the RADIAT code standard for initial array designs. The numerical code should be adequately sophisticated to model any radiator in use today as well as radiators that may be employed in the future.

It is difficult to accept as accurate existing codes which produce inaccurate impedance values. With the technical knowledge at hand it is possible to construct an accurate code which can be accepted by both the engineering and legal community. Without the Commission setting a standard code, it may be possible to hear the basics of electromagnetics debated in the courtroom.

Sufficient evidence exists around the country to find deficient the practice of using field intensity measurements. There are instances, however, where the practice must continue. With an accurate numerical code, one can have greater confidence that an array is properly adjusted as opposed to spending considerable iteration at the phasor controls in order to make field measurements fit desired conductivity curves.

Where it is not practical to employ loop sampling as described above, greater flexibility in field intensity measurement analysis should be allowed. Specifically, greater attention should be paid to the far field as opposed to the three to five kilometer range where the IDF is often calculated (by computer). Point scattering in that region due to reradiation may find itself sufficiently settled down at a greater distance due to the inefficiency of the reradiator.

The Commission should consider "pattern bandwidth" for new arrays that are to be employed in the expanded band. Pattern bandwidth concerns the variation in pattern shape as frequency is varied. This factor is ignored in the current Rules, however, modern computer techniques allow sophisticated phasor/coupling system designs which can provide minimal pattern variation within 10 Khz. It is in the licensees best interest to obtain best pattern and impedance bandwidth, especially in the AM stereo service.

It is the belief of this writer that sufficient technical advancements have been made over the years in order to justify the acceptance of this methodology. The methodology, however, must be uniform if it is to be successful.

References

[1] T.M. Bloomer "Antennas" Industrial Electronics Reference Book. John Wiley & Sons 1948. Chapter 20.

[2] Thomas G. Osenkowsky "A New Approach To AM Directional Antenna Stability Determination" Presented to the 39th Annual IEEE BTS Symposium on September 21, 1989.

[3] Valentin Trainotti "Height Radius Effect on MF AM Transmitting Monopole Antenna" IEEE Transactions on Broadcasting. March 1990 Volume 36 Number 1 Page 82.

THOMAS GARY OSENKOWSKY
Radio Engineering Consultant
5 Beechwood Grove
Brookfield, CT 06804
(203) 775-3060

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Certified Engineer

A NEW APPROACH TO AM DIRECTIONAL ANTENNA STABILITY DETERMINATION

Presented at the 39th Annual IEEE BTS Symposium

September 21, 1989

ABSTRACT

The stability of a directional antenna array is determined by different methods in theory and practice. In theory we apply a mathematical analysis to a multitower design in order to observe the effect of electrical parameter manipulation on the shape of the radiation pattern. The variations in radiated field are tested against the FCC Standard Pattern. The Standard Pattern is established using the theoretical field parameters. By using this technique, it is possible to determine the permissible field parameter deviation tolerances so that the Standard Pattern is not exceeded.

FCC Rules 73.150 and Appendix A contain the equations that are used to analyze directional radiation patterns. Equation 1 defines the pattern shape given the values of complex field radiated by each tower and the array geometry.

In practice, the fields radiated by each element in an array are not monitored directly. Customarily the current flowing in each element is sampled and fed via coaxial lines to the terminated ports of the antenna monitor (phase angle voltmeter). It is the purpose of this paper to discuss the relationship between the field and the current in the array elements and apply a comparison between the theoretical array stability and that realized in practice.

INTRODUCTION

The FCC uses a computer program called RADIAT to analyze directional antennas. RADIAT contains two subroutines MRV and SMKVAR for stability analysis. While the parameter manipulation algorithms used in these subroutines will not be addressed here it is important to keep in mind that the tower fields (field ratios compared to the reference tower) are used as the electrical parameters. These parameters are varied with each result being tested against the Standard Pattern.

In actual practice, the current amplitude and phase angle of each tower is sampled and used as an indication of array performance. FCC Rules specify a maximum deviation of +/- 5% for each tower's current ratio and +/- 3 degrees for phase angle.

Of concern to the aspect of stability is the location at which this current sample is taken. Three common locations are:

1 - At the tower base using a shielded toroidal transformer mounted inside the Antenna Tuning Unit.

2 - At the tower base using a rigid, fixed sampling loop. In this case the loop must be located at least 3 meters above the base insulator to avoid ground effects (former FCC 73.68).

3 - At the current loop (current maxima) on the tower using a rigid loop.

Rigid loops are available in two sizes, the larger size used in low power arrays where a greater terminal current-to-voltage ratio is needed. Most loops have movable shorting bars so that the sample voltage can be set at the initial tuneup.

DISCUSSION

We are looking for a relationship between the field ratio and the monitored current ratio. Since the values are different, we cannot interchange the two for use in Equation 1. It is necessary to mathematically derive the relationship between the field, loop and base values. With a non-linear correlation between the three values, applying fixed tolerances of 5% and 3 degrees will produce different patterns which may exceed the Standard. This would be evidenced by converting the new base or loop parameters back to the field values and using the new field values in Equation 1. By examining a three tower array using the Moment Method and matrix inversion, it will be shown that an accurate model can be constructed which will relate the field parameters to the sample parameters.

Let us consider the following array:

TWR	HEIGHT	FIELD	PHASE	SPACING	ORIENT
1	126	.437	-139	72	340
2	115	1.00	0	17.5	250
3	126	.553	+145	72	160

Using the Moment Method, the following driving point and loop parameters are calculated for a power of 5000 watts:

TWR	I RATIO	I PHASE	VOLTS	E PHASE	L RATIO	L PHASE
1	.133	178.97	1510.9	-122.27	.418	-137.8
2	1.0	0	2321.0	0	1.0	0
3	.476	139.20	1132.8	152.1	.509	145.4

Table 1 shows the results of varying tower #1 and tower #3 base ratio and phase +5% and +3 degrees independently. As can be seen from the results of these manipulations, the relationship between loop, base and field ratio and phase angle is not a linear one.

Table 1

Increase Tower #1 Base Current by 5%

TWR	F RATIO	F PHASE	L RATIO	L PHASE	DELTA F	DELTA L
1	.441	-140.0	.422	-138.9	+.92%	+.95%
2	1.000	0	1.000	0		
3	.550	145.0	.505	145.4	+.55%	-.79%

Increase Tower #1 Base Phase Angle by +3 Degrees

TWR	F RATIO	F PHASE	L RATIO	L PHASE	DELTA F	DELTA L
1	.440	-138.8	.421	-137.7	+.68%	+.71%
2	1.000	0	1.000	0		
3	.553	144.9	.507	145.3	0%	-.39%

Increase Tower #3 Base Current By 5%

TWR	F RATIO	F PHASE	L RATIO	L PHASE	DELTA F	DELTA L
1	.440	-138.2	.422	-140.1	+.68	+.95%
2	1.000	0	1.000	0		
3	.578	143.7	.530	144.1	+4.5%	+4.1%

Increase Tower #3 Base Phase Angle By +3 Degrees

TWR	F RATIO	F PHASE	L RATIO	L PHASE	DELTA F	DELTA L
1	.431	-138.6	.413	-137.4	-1.4%	-1.2%
2	1.000	0	1.000	0		
3	.567	147.7	.520	148.1	+2.5%	+2.2%

Before discussing the results in detail it will be pointed out that, in the case of this actual array, the sampling loops are each mounted 3 meters above each tower base. This location is actually a modified base sample. Table 2 shows the current distribution for all towers up to the current loop for the theoretical parameters. Note that the current loop is not exactly at the same physical height for the end two towers. As can be easily seen, the base area for tower #1 is highly changing in current amplitude and phase angle. This is attributed to the fact that tower #1 is negative, and the calculated drive point impedance is -1000+j1221. A toroid sample and base loop can be expected to show widely different results. The toroid will also show different results due to the inclusion of the series lightning retard loop (an inductance). Lastly, but not least, it must be recognized that tower #2 is electrically shorter than #1 and #3 and thus true electrical base sampling is not employed here.

The geometry of an array may not contribute to stability as greatly as the electrical parameters. Consider the night pattern for the same array as shown below.

TWR	HEIGHT	FIELD	PHASE	SPACING	ORIENT
1	126	.584	+175	72	340
2	115	1.00	0	17.5	250
3	126	.684	-159	72	160

Using the Moment Method, the following driving point and loop parameters are calculated for a power of 500 watts:

TWR	I RATIO	I PHASE	VOLTS	E PHASE
1	.452	175.12	624.5	-177.7
2	1.0	0	1066.1	0
3	.410	-160.8	860.6	+11.5

Now the same manipulations as performed previously will be repeated for the new pattern. For this example, only the field and base are considered.

Increase Tower #1 Base Current by 5%

TWR	F RATIO	F PHASE	DELTA F
1	.608	+173.9	+4.1%
2	1.000	0	
3	.680	-158.7	-.58%

Increase Tower #1 Base Phase Angle by +3 Degrees

TWR	F RATIO	F PHASE	DELTA F
1	.599	+177.7	+2.6%
2	1.000	0	
3	.678	-159.6	-.88%

Increase Tower #3 Base Current By 5%

TWR	F RATIO	F PHASE	DELTA F
1	.576	+175.4	-1.4%
2	1.000	0	
3	.706	-160.4	+3.2%

Increase Tower #3 Base Phase Angle By +3 Degrees

TWR	F RATIO	F PHASE	DELTA F
1	.582	+174.5	-.34%
2	1.000	0	
3	.699	-157.3	+2.2%

Table 3 shows the current and phase distribution for the towers operated with the theoretical field parameters.

Table 3

Tower #1

HEIGHT ABOVE TOWER BASE	CURRENT MAG	PHASE
124.7	.732	171.504
113.3	1.311	171.598
102.0	1.823	171.697
90.7	2.258	171.806
79.3	2.602	171.927
68.0	2.844	172.064
56.7	2.974	172.226
45.3	2.985	172.424
34.0	2.873	172.680
22.7	2.632	173.035
11.3	2.257	173.588
.0	1.555	175.118

Tower #2

HEIGHT ABOVE TOWER BASE	CURRENT MAG	PHASE
112.7	1.448	-3.873
101.5	2.574	-3.741
90.2	3.550	-3.606
78.9	4.357	-3.461
67.6	4.975	-3.298
56.4	5.382	-3.110
45.1	5.562	-2.881
33.8	5.503	-2.589
22.5	5.192	-2.185
11.3	4.614	-1.571
.0	3.443	.000

Tower #3

HEIGHT ABOVE TOWER BASE	CURRENT MAG	PHASE
124.7	.922	-162.198
113.3	1.639	-162.200
102.0	2.261	-162.198
90.7	2.776	-162.186
79.3	3.169	-162.163
68.0	3.426	-162.125
56.7	3.537	-162.071
45.3	3.493	-161.995
34.0	3.291	-161.894
22.7	2.925	-161.753
11.3	2.386	-161.531
.0	1.410	-160.836

Comparing the phase distribution to the day pattern, it is readily observed that a far less radical rate of change occurs on all three towers. Placement of sample loops at the base (3 meters above ground) would not produce greatly differing results than toroids mounted at the ATU.

Analysis of the night pattern shows again the non-linear field to base correlation. As expected, the field to loop correlation is somewhat better.

Another consideration for stability is the mode of the array design. Mode refers to the choice of parameter option(s) available to the designer. For symmetrical arrays and certain parallelograms there exists 2n-1 number of parameter options which produce the same pattern but with different driving point impedances and power distributions. The exception to this rule is the case of the unity field ratio. Exception must also be made for unequal height symmetrical arrays. By moding such arrays the horizontal pattern will remain constant, however, the vertical patterns will be different thus violating the original design. Asymmetrical arrays have only one mode, this involving movement of a tower(s). Let us examine the simple two tower array in Figure 1. The elements are 90 electrical degrees tall and spaced 90 electrical degrees. Shown are both modes of operation.

Figure 1

Mode 1

TWR	F RATIO	F PHASE	Z BASE	POWER	I BASE
1	1.000	0	53.4+j32.3	904.2	4.115
2	.600	90	13.2-j13.5	95.8	2.699

Mode 2

TWR	F RATIO	F PHASE	Z BASE	POWER	I BASE
1	.600	0	77.4+j54.6	433.0	2.365
2	1.000	90	30.4+j7.7	567.0	4.316

By increasing base current #2 in each mode by +5% the Delta F for mode 1 was 5.16% and for mode 2 the Delta F was 4.52%. While some few believe that mode 1 will yield a better bandwidth than mode 2 it should be noted that mathematically, a greater rate of change occurs at tower #1 using mode #1 thus causing a greater amount of instability.

While touching upon the important topic of bandwidth, both from a pattern and impedance standpoint, the design of the phasing system will also play an important role in the stability of the array. In the models above, each tower base was assumed to be fed by a perfect voltage generator. In reality, a common voltage generator is used (the transmitter) and a passive power divider and phasing system is employed. The design of the networks plays an important role in how stable the system will remain. The mode of the array determines the value of base operating impedance and amount of power which the system must feed. Improper choice of networks, transmission line lengths and L-C ratios can cause instability. It must be remembered that we are dealing with a coupled system where mutual interaction between the elements must be considered.

CONCLUSION

While base sampling has the advantages of not needing isolation coils and having the current sampling transformer located outside the influence of the elemnts, a careful analysis should be undertaken for arrays with tall towers or unusual operating parameters. With the wide availability of Moment Method programming tools, it is possible to construct a model of the current (or voltage) sampled location vector sensitivity matrix versus the field parameter sensitivirty matrix so that the actual effects of changes in the antenna monitor readings can be translated into predicted variations in the radiation pattern.
It is further possible to model the entire phasing system given the exact component values and measured (preferred) or predicted base and mutual impedances so that sensitive component values can be identified. In such cases it may be possible to employ a new phasing scheme to eliminate the problem or choose components with tighter tolerances. Of prime importance is the correct selection of sampling locations so that an accurate portrayl of actual array operation is displayed on the station's antenna monitor.